SOLID-STATE IMAGING DEVICE AND METHOD FOR PRODUCING THE SAME

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION:

The present invention relates to a solid-state imaging device, and in particular to a solid-state imaging device structured so as to enhance the sensitivity of a light reception section thereof and a method for producing such a device.

2. DESCRIPTION OF THE RELATED ART:

In recent years, the transmission and reception of images is becoming indispensable to portable information devices and the like including cellular phones. So-called solid-state imaging devices such as CCDs are used for imaging purposes while liquid crystal panels are used for displaying images. In the field of solid-state imaging devices, CMOS image sensors based on a so-called CMOS logic process, which is typically used for producing a normal integrated circuit, are widely developed with a view to achieving low power consumption and a low cost. As in the case of CCDs, the demand for higher resolution and miniaturization has necessitated CMOS image sensors having reduced pixel size, as well as having a reduced area of the light reception section, and

a reduced aperture size in a light shielding film. However, since CMOS image sensors have so far been developed based on the so-called logic process, very little attention has been paid to the optical characteristics of CMOS image sensors, such as reflection or refraction at interfaces between the layers of multi-layered films incorporated therein. Therefore, it is difficult with CMOS image sensors to efficiently converge incident light and obtain sufficient sensitivity.

A conventional solid-state imaging device, in particular a CMOS image sensor, will be described with reference to Figure 5. A light reception section 12 is formed on a top surface of a silicon substrate 11 for converting incident light (hv) to an electric charge. An interlaminar insulation film 13 is formed on the silicon substrate 11 for electrically isolating a first metal layer 18, a second metal layer 19, and a light shielding film 14 from one another. The light shielding film 14 is formed so as not to overlie a light reception face of the light reception section 12, so that light incident on the interlaminar insulation film 13 does not fall anywhere except the light reception section 12. A

passivation film **15** is formed on the light shielding film **14** and on the interlaminar insulation film **13** which is present within an aperture of the light shielding film **14**. The passivation film **15** provides moisture-resistance, chemical resistance, and improved barrier properties against impurities such as Na ions, oxygen, etc., and metals. A planarization film **16** is formed on the passivation film **15**. A microlens **17** is formed for converging light which is incident on the planarization film **16**. As the interlaminar insulation film **13**, a deposited film such as a P (plasma CVD)-SiO_2 film, an NSG film (a silicon oxide film containing no impurities), a BPSG film (a silicon oxide film containing phosphorus and boron) or the like is used. As the passivation film **15**, a monolayer film, such as a P (plasma CVD)-SiN film, or a deposited film composed of a P-SiN film and a PSG film (a silicon oxide film containing phosphorus), is generally used. The planarization film **16** is generally composed of an acrylic material. In the case of a color solid-state imaging device, an acrylic material and a color filter are utilized as the planarization film **16**. In conventional CMOS image sensor structures, the passivation film **15** has a stepped portion as described above, which prevents the convergence of light. When such

a structure is adapted for higher resolution and miniaturization, the stepped portion of the passivation film **15** causes a decrease in the amount of light converged on the light reception section **12**, thereby making it difficult to obtain sufficient sensitivity.

A method for producing the above-described device will now be described with reference to Figure **6**. The light reception section **12** is formed in the silicon substrate **11** through ion implantation, heat treatment, etc. After forming a polycrystalline silicon film and a silicide film on the silicon substrate **11** by using a CVD technique, a gate electrode (not shown) is formed by patterning, etching, or the like. Thereafter, a BPSG film is deposited as the interlaminar insulation film **13** by a CVD technique. When the BPSG film receives heat treatment at a high temperature, the film becomes fluid so that its surface can be flattened. By taking advantage of such characteristics of the BPSG film, the surface of the BPSG film is flattened so as to facilitate the formation of the first metal layer **18**. The first metal layer **18** is formed by depositing TiN, Al or the like on the BPSG film by using a sputtering or CVD technique. Upon the first metal layer **18**, the P-SiO_2 film is deposited as

the interlaminar insulation film **13** by using a CVD technique and the surface thereof is flattened by chemical machine polishing. Thereafter, as in the case of the first metal layer **18**, a thin film of TiN, Al, or the like is formed as the second metal layer **19** by using a sputtering or CVD technique. Similarly, upon the second metal layer **19**, a P-SiO_2 film is deposited as the interlaminar insulation film **13** by using a CVD technique and the surface thereof is flattened by the chemical machine polishing. Thereafter, TiN, Al, or the like is deposited as the light shielding film **14** by using a sputtering or CVD technique, and the resultant film is patterned and etched so as not to overlie the light reception section **12**. Upon the light shielding film **14**, a P-SiN film is deposited as the passivation film **15** by using a CVD technique or the like. The planarization film **16** is formed by applying an acrylic material to the passivation film **15**. In the case of a color solid-state imaging device, an acrylic material is applied; a color filter is formed; and then the acrylic material is further applied thereto as a protection coating, thereby completing the planarization film **16**. Thereafter, a lens material is applied and the microlens **17** is formed by patterning and heat treatment.

In a conventional solid-state imaging device shown as Figure **5A**, the refractive index of the P-SiN film used for the passivation film **15** is about 2.0 while the refractive index of the acrylic material used for the planarization film **16** is about 1.5 to 1.6. In the case where the refractive index of the passivation film **15** is higher than that of the planarization film **16**, when light falls onto an edge of the passivation film **15**, the incident light is not converged on the light reception section **12** but rather refracted so as to travel outside the light reception section **12** toward the first metal layer **18** or the second metal layer **19** since the edge of the passivation film **15** has a rounded shape. As shown in an enlarged view of Figure **5B**, when light falls onto the flat top surface of the stepped portion, total internal reflection can occur at an interface between the planarization film **16** and a face of the passivation film **15** parallel to a side face of the light shielding film **14**, depending on the incident angle of the light, since the refractive index of the passivation film **15** is higher than that of the planarization film **16**. The incident light passes along the face of the passivation film **15** parallel to the side face of the light shielding

film 14 so that the light is not converged on the light reception section 12. As described above, in the conventional structure shown as Figure 5A, any light incident on a portion of the passivation film 15 neighboring the side face of the light shielding film 14 is not converged on the light reception section 12. Therefore, the effective aperture size of the light shielding film 14 is smaller than the actual aperture size by an amount corresponding to the thickness of the passivation film 15.

The light reception face of the light reception section 12 used to be sufficiently large relative to the stepped portion of the passivation film 15. However, due to the reduced pixel size which is necessitated for improved resolution and miniaturization, the light reception face of the light reception section 12 is becoming smaller and the aperture of the light shielding film 14 is also becoming narrower. Therefore, the ratio of the amount of light incident on the stepped portion of the passivation film 15 to the amount of light incident on the aperture of the light shielding film 14 increases, thereby making it difficult to obtain sufficient sensitivity. However, the passivation film 15 can not

be omitted because the passivation film **15** plays an important role in providing moisture-resistance, chemical resistance and/or improved barrier properties against impurities such as Na ions, oxygen, etc., and metals.

The effect of the stepped portion of the passivation film **15** on the numerical aperture of the light shielding film **14** will now be described in detail. Provided that the sensitivity deteriorates by an amount corresponding to the thickness of the passivation film **15**, the aperture size can be represented as (pixel size) - (width of the light shielding film) - (2 × thickness of the passivation film **15**). For example, in the case where the width of the light shielding film **14** is 1.5 μm, and the thickness of the passivation film **15** is 0.5 μm, given a pixel size of 10 μm × 10 μm, the aperture of the light shielding film **14** is calculated to be 10 - 1.5 - (0.5 × 2) = 7.5 μm, and therefore, the numerical aperture is 75%. Similarly, given a pixel size of 5 μm × 5 μm, the aperture of the light shielding film **14** is calculated to be 5 - 1.5 - (0.5 × 2) = 2.5 μm, and therefore, the numerical aperture is 50%. Starting from the above one-dimensional calculation, it will be seen that the numerical aperture

area as calculated in a two-dimensional manner gives rise to an even greater difference in the size (area) between the aperture and each pixel. The reduction in the numerical aperture of the light shielding film **14** is highly detrimental to the ratio of light incident on the light reception face of the light reception section **12**; this effect is more detrimental than any reduction in the numerical aperture of layers below the light shielding film **14**.

SUMMARY OF THE INVENTION

According to one aspect of this invention, there is provided a solid-state imaging device, including a semiconductor substrate, a light shielding section having an aperture for partially shielding light incident on a surface of the semiconductor substrate, a light reception section for converting the light which is incident on the surface of the semiconductor substrate through the aperture to an electric charge, and a passivation section having a substantially flat top surface and overlying the light shielding section, the light reception section and the aperture.

According to one embodiment of the invention, the passivation section includes at least a silicon nitride-based monolayer film.

According to another embodiment of the invention, a solid-state imaging device further includes an insulation section having a substantially flat top surface which is interposed between the passivation section and the light shielding section.

According to still another embodiment of the invention, the insulation section includes at least a silicon oxide-based monolayer film.

According to another aspect of the invention, there is provided a method for producing a solid-state imaging device which includes a semiconductor substrate, a light shielding section having an aperture for partially shielding light incident on a surface of the semiconductor substrate, a light reception section for converting the light which is incident on the surface of the semiconductor substrate through the aperture to an electric charge, and a passivation section having a substantially flat top surface and overlying the light

shielding section, the light reception section and the aperture, and the method includes the steps of forming a thin film used for forming the passivation section on the light shielding section and the aperture, and flattening a surface of the thin film to form the passivation section by chemical machine polishing.

According to still another aspect of the invention, there is provided a method for producing a solid-state imaging device which includes a semiconductor substrate, a light shielding section having an aperture for partially shielding light incident on a surface of the semiconductor substrate, a light reception section for converting the light which is incident on the surface of the semiconductor substrate through the aperture to an electric charge, and a passivation section having a substantially flat top surface and overlying the light shielding section, the light reception section and the aperture, and the method includes the steps of forming a thin film used for forming the passivation section on the light shielding section, applying an SOG film to the thin film used for forming the passivation section, and performing an etchback technique under a condition that a selective ratio of the SOG film to the thin film used

for forming the passivation section is about 1 to 1.

According to still another aspect of the invention, there is provided a method for producing a solid-state imaging device which includes a semiconductor substrate, a light shielding section having an aperture for shielding light incident on a surface of the semiconductor substrate, a light reception section for converting the light which is incident on the surface of the semiconductor substrate through the aperture to an electric charge, a passivation section having a substantially flat top surface and overlying the light shielding section, the light reception section and the aperture, and an insulation section having a substantially flat top surface which is interposed between the passivation section and the light shielding section, and the method includes the steps of forming the insulation section on the light shielding section, flattening a surface of the insulation section by chemical machine polishing, and forming the passivation section so as to have the substantially flat top surface by depositing a material used for forming the passivation section on the insulation section.

According to still another aspect of the invention,

there is provided a method for producing a solid-state imaging device which includes a semiconductor substrate, a light shielding section having an aperture for partially shielding light incident on an surface of the semiconductor substrate, a light reception section for converting the light which is incident on the surface of the semiconductor substrate through the aperture to an electric charge, a passivation section having a substantially flat top surface and overlying the light shielding section, a light reception section and the aperture, and an insulation section having a substantially flat top surface which is interposed between the passivation section and the light shielding section, and the method includes the steps of forming the insulation section so as to have the substantially flat top surface by applying an SOG film to the light shielding section and the aperture, and forming the passivation section so as to have the substantially flat top surface by depositing a material used for forming the passivation section on the insulation section.

In order to achieve the above-described objectives, according to the present invention, a passivation film is deposited on an interlaminar

insulation film so as to have a thickness which is greater than that of a light shielding film. Thereafter, a portion of the thickly deposited passivation film is removed, to such an extent that the light shielding film is not exposed, by chemical machine polishing or by using an etchback technique after applying an SOG to the passivation film. Thus, a surface of the passivation film is flattened.

Alternatively, a silicon oxide-based insulation film is thickly deposited on the light shielding film and the interlaminar insulation film in the manner described above. Thereafter, a portion of the resultant film is removed, to such an extent that the light shielding film is not exposed, by using chemical machine polishing. Thus, a surface of the film is flattened. A passivation film is then deposited on a top surface of the silicon oxide-based insulation film. Since the top surface of the silicon oxide-based insulation film is flat, the top surface of the passivation film, which is deposited on the insulation film, also becomes flat. Therefore, the passivation film is prevented from having any stepped portion, which is one problem associated with a conventional passivation film.

Alternatively, an SOG film is applied on the light shielding film and the interlaminar insulation film. The passivation film is then deposited on a top surface of the SOG film. Since the top surface of the SOG film is flat, the top surface of the passivation film, which is deposited on the SOG film, also becomes flat. Therefore, the passivation film is prevented from having any stepped portion, which is one problem associated with a conventional passivation film.

As described above, through the use of the aforementioned techniques, according to the present invention, the passivation film is prevented from having any stepped portion, which is one problem associated with a conventional passivation film. Therefore, a component of light which would otherwise fall onto stepped areas to be refracted in directions away from the light reception section can be converged on the light reception section. Thus, the imaging device according to the present invention can be adapted for higher resolution and miniaturization.

Thus, the invention described herein makes

possible the advantages of: (1) providing a solid-state imaging device which can converge incident light on a light reception section thereof due to the absence of stepped portions on a passivation film; and (2) providing a method for producing such a solid-state imaging device.

These and other advantages of the present invention will become apparent to those skilled in the art upon reading and understanding the following detailed description with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a cross-sectional view of a solid-state imaging device according to Example 1 of the present invention.

Figure 2 is a cross-sectional view of a solid-state imaging device according to Example 2 of the present invention.

Figures 3A, 3B, 3C, 3D, 3E, and 3F are cross-sectional views illustrating production steps of a solid-state imaging device according to Example 1 of the

present invention.

Figure **4A**, **4B**, **4C**, **4D**, **4E**, **4F** and **4G** are cross-sectional views illustrating production steps of a solid-state imaging device according to Example 2 of the present invention.

Figure **5A** is a cross-sectional view illustrating a structure of a conventional solid-state imaging device.

Figure **5B** is a partial enlarged view of Figure **5A**.

Figures **6A**, **6B**, **6C**, **6D**, **6E**, and **6F** are cross-sectional views illustrating production steps of a conventional solid-state imaging device.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Examples of the present invention will be described below in detail with reference to drawings.

(Example 1)

A basic structure of Example 1 of the present invention is shown in Figure 1. As shown in Figure 1,

a light reception section 2 for converting incident light to an electric charge is formed on a top surface of a silicon substrate 1. An interlaminar insulation film 3 for electrically isolating a first metal layer 8, a second metal layer 9, and a light shielding film 4 from one another is formed on the silicon substrate 1. The light shielding film 4 is formed on the interlaminar insulation film 3 without overlying, a light reception face of the light reception section 2, so that incident light does not fall anywhere except the light reception section 2. A passivation film 5 is formed on the light shielding film 4 and on the interlaminar insulation film 3 which is present within an aperture of the light shielding film 4 in order to provide moisture-resistance, chemical resistance, and improved barrier properties against impurities such as Na ions, oxygen, etc., and metals. A portion of the passivation film 5 is removed, to such an extent that the light shielding film 4 is not exposed, by using chemical machine polishing or an etchback technique. Thus a surface of the passivation film is flattened. A planarization film 6 is formed on the passivation film 5. A microlens 7 is formed for converging light which is incident on the planarization film 6. In Example 1, the passivation film 5 may be in

the form of a SiN-based monolayer film, or a deposited film composed of a SiN-based film, having a refractive index of about 2.0. An acrylic material is used for the planarization film **6**, having a refractive index of about 1.5 to 1.6.

In conventional structures, the passivation film **15** would have a stepped portion as shown in Figure **5A** and **5B**. Light incident on the stepped portion is refracted in directions away from the light reception section, due to the different refractive index of an edge of the stepped portion. Since the refractive index of the passivation film **15** is higher than that of the planarization film **16**, total internal reflection occurs at an interface between the planarization film **16** and a face of the passivation film **15** parallel to a side face of the light shielding film **14**, so that incident light is not converged on the light reception section **12**. However, in the structure according to Example 1 of the present invention, the passivation film **5** is thickly deposited and a top surface thereof is flattened by chemical machine polishing or an etchback technique, so that any refraction of incident light associated with a stepped portion, as in the case of the passivation film **15**

of conventional structures, does not occur. As a result, most of light converged by the microlens **7** is converged on the light reception section **2**.

A method for producing a solid-state imaging device according to Example 1 of the present invention will now be described with reference to Figure **3A**, **3B**, **3C**, **3D**, **3E**, and **3F**. The light reception section **2** is formed in the silicon substrate **1** through ion implantation, heat treatment, etc. (Figure **3A**). After forming a polycrystalline silicon film and a silicide film on the silicon substrate **1** by using a CVD technique, a gate electrode (not shown) is formed by patterning, etching, or the like. Thereafter, a BPSG film is deposited so as to have a thickness of about 5000 Å to 15000 Å as the interlaminar insulation film **3** by a CVD technique. By subjecting the BPSG film to heat treatment at about 850 to 950℃, its surface is flattened so as to facilitate the formation of the first metal layer **8**. The first metal layer **8** is formed by depositing TiN to a thickness of about 300 Å to 1000 Å and Al to a thickness of about 3000 Å to 10000 Å on the BPSG film by using a sputtering or CVD technique (Figure **3B**). Upon the first metal layer **8**, a P-SiO_2 film having a thickness of about

20000 Å to 25000 Å is deposited as the interlaminar insulation film **3** by using a CVD technique, and a thickness of about 10000 Å is removed from the resultant film by chemical machine polishing, thereby flattening the film surface. Thereafter, as in the case of the first metal layer **8**, TiN having a thickness of about 300 Å to 1000 Å and Al having a thickness of about 3000 Å to 10000 Å are deposited as the second metal layer **9** by using a sputtering or CVD technique (Figure **3C**). Similarly, upon the second metal layer **9**, a P-SiO_2 film having a thickness of about 20000 Å to 25000 Å is deposited as the interlaminar insulation film **3** by using a CVD technique and a thickness of about 10000 Å is removed from the resultant film by chemical machine polishing, thereby flattening the film surface. Thereafter, TiN having a thickness of about 300 Å to 1000 Å and Al having a thickness of about 3000 Å to 10000 Å are deposited as the light shielding film **4** by using a sputtering or CVD technique, and the resultant film is patterned and etched so as not to overlie the light reception section **2** (Figure **3D**). Upon the light shielding film **4**, a P-SiN film having a thickness of 20000 Å is deposited as the passivation film **5**. Thereafter, a thickness of about 10000 Å is removed from the P-SiN film by chemical machine

polishing, thereby flattening the film surface (Figure 3E). In another way of flattening, conventional production steps are used so as to form the light shielding film 4, and thereafter, a P-SiN layer is thickly deposited as the passivation film 5 by using a CVD technique or the like.

Thereafter, SOG is applied to a top surface of the passivation film 5 and a top surface of the resultant film is etched by using an RIE under an etching condition such that the selectivity ratio of the P-SiN to the SOG is about 1:1, thereby flattening the top surface of the passivation film 5. More particulaly, the light shielding film 4 is deposited so as to have a thickness of about 3000 Å to 10000 Å, and a P-SiN film having a thickness of about 20000 Å is deposited as the passivation film 5. SOG is applied to the P-SiN film so as to have a thickness of about 15000 Å. A 1:1 selectivity ratio of P-SiN to SOG can be obtained under the following RIE etching conditions: pressure: 4 to 15 Pa; CHF_3: 20 to 50 sccm; CF_4: 20 to 50 sccm; Ar: 50 to 100 sccm; O_2: 1 to 5 sccm; and RF: 200 to 700 W. By performing etching under such conditions, the top surface of the P-SiN film can be flattened (Figure 3E). After flattening the top surface

of the passivation film **5**, a planarization film **6** is formed by applying an acrylic material to the passivation film **5**. In the case of a color solid-state imaging device, an acrylic material is applied; a color filter is formed; and then the acrylic material is further applied thereto as a protection coating, thereby completing the planarization film **6**. Thereafter, a lens material is applied to the planarization film **6**, and the microlens **7** is formed by patterning and heat treatment (Figure **3F**).

Since the stepped portions of the passivation film **5** are eliminated, the aperture of the light shielding film **4** can be represented as (pixel size) - (width of light shielding film). For example, in the case where the width of the light shielding film **4** is 1.5 μm, given a pixel size of 5 μm × 5 μm, the aperture of the light shielding film **4** is calculated to be 5 - 1.5 = 3.5 μm, and therefore, the numerical aperture is 70%. Since the conventional numerical aperture is 50%, the numerical aperture of the present example is improved so as to be 1.4 times the conventional numerical aperture.

(Example 2)

Example 2 of the present invention will now be

described.

A basic structure of Example 2 of the present invention is shown in Figure 2. As shown in Figure 2, a light reception section 2 for converting incident light to an electric charge is formed on a top surface of a silicon substrate 1. An interlaminar insulation film 3 for electrically isolating a first metal layer 8, a second metal layer 9, and a light shielding film 4 from one another is formed on the silicon substrate 1. The light shielding film 4 is formed on the interlaminar insulation film 3 without overlying a light reception face of the light reception section 2, so that incident light does not fall anywhere except the light reception section 2. A silicon oxide film 10 is formed on the light shielding film 4 and on the interlaminar insulation film 3 which is present within an aperture of the light shielding film 4. A portion of the silicon oxide film 10 is removed, to such an extent that the light shielding film 4 is not exposed, by using chemical machine polishing. Thus a surface of the silicon oxide film 10 is flattened. When the silicon oxide film 10 is formed by application of SOG, a silicon oxide film having a flat top surface can be formed without performing chemical machine polishing. A

passivation film **5** is formed on the silicon oxide film **10** in order to provide moisture-resistance, chemical resistance, and improved barrier properties against impurities such as Na ions, oxygen, etc., and metals. A planarization film **6** is formed on the passivation film **5**. A microlens **7** is formed for converging light which is incident on the planarization film **6**.

In Example 2, because it is more advantageous to flatten the top surface of the silicon oxide-based film than to flatten the top surface of the P-SiN film, it is easier to apply chemical machine polishing to the silicon oxide film **10** than to the P-SiN passivation film **5** for the following reasons. Firstly, a silicon oxide-based film can be relatively easily etched since its etching rate is faster than that of the P-SiN film. Secondly, since chemical machine polishing is performed at the time of forming the interlaminar insulation film **3**, a conventional chemical machine polishing technique can be applied to the silicon oxide-based film. Since the passivation film **5** is deposited on the silicon oxide film **10** after the top surface of the silicon oxide film **10** is flattened, a top surface of the passivation film **5** can also be flattened. Thus, the stepped portion of the

passivation film 5 shown in Figure 5A can be eliminated, so that light which is converged by the microlens 7 on the light reception section 2 can be converged without being obstructed.

A method for producing a solid-state imaging device according to Example 2 will now be described with reference to Figure 4. Production steps of the conventional method and Example 1 are used in Example 2 so as to form the light shielding film 4. The light reception section 2 is formed in the silicon substrate 1 through ion implantation, heat treatment, etc. (Figure 4A). After forming a polycrystalline silicon film and a silicide film on the silicon substrate 1 by using a CVD technique, a gate electrode (not shown) is formed by patterning, etching, or the like. Thereafter, a BPSG film having a thickness of about 5000 Å to 15000 Å is deposited as the interlaminar insulation film 3 by a CVD technique. By subjecting the BPSG film to heat treatment at about 850 to 950℃, its surface is flattened so as to facilitate the formation of the first metal layer 8. The first metal layer 8 is formed by depositing TiN to a thickness of about 300 Å to 1000 Å and Al to a thickness of about 3000 Å to 10000 Å on the BPSG film by

using a sputtering or CVD technique (Figure 4B). Upon the first metal layer 8, a P-SiO_2 film having a thickness of about 20000 Å to 25000 Å is deposited as the interlaminar insulation film 3 by using a CVD technique, and a thickness of about 10000 Å is removed from the P-SiN film by chemical machine polishing, thereby flattening the film surface. Thereafter, as in the case of the first metal layer 8, TiN having a thickness of about 300 Å to 1000 Å and Al having a thickness of about 3000 Å to 10000 Å are deposited as the second metal layer 9 by using a sputtering or CVD technique (Figure 4C). Similarly, upon the second metal layer 9, a P-SiO_2 film having a thickness of about 20000 Å to 25000 Å is deposited as the interlaminar insulation film 3 by using a CVD technique, and a thickness of about 10000 Å is removed from the P-SiO_2 film by chemical machine polishing, thereby flattening the film surface. Thereafter, TiN having a thickness of about 300 Å to 1000 Å and Al having a thickness of about 3000 Å to 10000 Å are deposited as the light shielding film 4 by using a sputtering or CVD technique, and the resultant film is patterned and etched so as not to overlie the light reception section 2 (Figure 4D). As described above, production steps of the conventional method are used so as to form the light shielding film 4. Thereafter,

the silicon oxide film **10** having a thickness of about 20000 Å to 25000 Å is deposited by using a CVD technique and a thickness of about 10000 Å is removed from the resultant film by a chemical machine polishing (Figure **4E**). Thereafter, a P-SiN film **5** having a thickness of about 3000 Å to 10000 Å is deposited on the silicon oxide film **10**, thereby flattening a top surface of the P-SiN film **5** (Figure **4F**).

In another way of flattening, conventional production steps are used so as to form the light shielding film **4**, and thereafter, SOG is applied to the light shielding film **4** as the silicon oxide film **10** (Figure **4E**). A P-SiN film **5** is deposited on the flattened silicon oxide film **10**, which is formed of an SOG film, so as to obtain the P-SiN film **5** having a flat top surface (Figure **4F**). In this case, the applied SOG film has a thickness of about 10000 Å to 15000 Å, and the P-SiN film **5** having a thickness of about 3000 Å to 10000 Å is deposited by a CVD technique. Thereafter, the planarization film **6** is formed by applying an acrylic material to the P-SiN film **5**. In the case of a color solid-state imaging device, an acrylic material is applied; a color filter is formed; and then the acrylic material is further applied thereto

as a protection coating, thereby completing the planarization film **6**. Thereafter, a lens material is applied thereto and the microlens **7** is formed by patterning and heat treatment (Figure **4G**).

As described above, according to the present invention, the stepped portion can be eliminated by flattening a top surface of the passivation film, so that incident light can be converged on the light reception section. Therefore, the present invention makes it possible to provide a solid-state imaging device which is capable of efficiently converging incident light on a light reception section thereof so as to be adapted for reduced pixel size.

Various other modifications will be apparent to and can be readily made by those skilled in the art without departing from the scope and spirit of this invention. Accordingly, it is not intended that the scope of the claims appended hereto be limited to the description as set forth herein, but rather that the claims be broadly construed.